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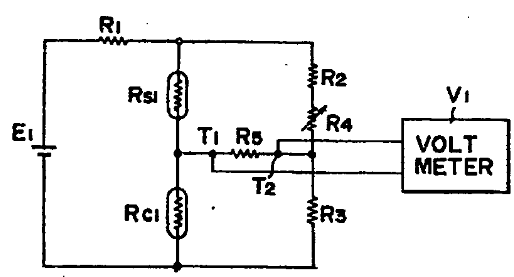
(54) Humidity measuring method and hygrometer to carry out the method.

(57) A current is applied to a thermistor (R_{S1}) or like heat sensitive element having a temperature-resistance characteristic to heat the heat sensitive element up to a temperature above the open air temperature and the heat sensitive element (R_{S1}) is held in the open air. Since the resistance value of the heat sensitive element (R_{S1}) varies with the amount of water vapor contained in the open air, the change in the resistance value is detected, from which the humidity of the open air is obtained. By temperature compensation with a temperature compensating element (R_{C1}) which is completely held in the dry state, direct reading of absolute or relative humidity is made possible.



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Humidity measuring method and hygrometer to carry out the method.

This invention relates to a humidity measuring method and a hygrometer for electrically measuring humidity with high accuracy.

Heretofore, there have been employed a psychrometer, a hair hygrometer, a dew-point hygrometer, an absorption hygrometer and so forth for humidity measurement. The psychrometer is inexpensive and appreciably high in the accuracy of measurement, and hence is employed relatively widely; but this hygrometer requires constant wetting of a wet-bulb with water and therefore involves a water supply or replacement of a moisture absorbing gauze. The hair hygrometer is not satisfactory in the accuracy of measurement and the dew-point hygrometer involves cumbersome operations.

The absorption hygrometer is used for measurement of absolute humidity. In this case, a constant amount of air is passed through a U-shaped tube containing phosphorus pentoxide (P_2O_5) to entirely absorbe water vapor in the air by the phosphorus pentoxide and an increase in the mass of the phosphorus pentoxide is measured; since the increase in the mass corresponds to the water content in the air, the absolute humidity is obtained. But the absorption hygrometer is defective in that its measuring operation is complex.

It is an object of the present invention to electrically measure humidity easily with high accuracy and to provide a hygrometer to carry out such measurement.

Another object of the present invention is to permit direct reading of absolute humidity.

Yet another object of the present invention is to permit direct reading of relative humidity.

The problem underlying the invention is solved by a humidity measuring method characterized in that a current is applied to a heat sensitive element having a temperature- resistance characteristic to heat it up to a temperature above the open air temperature; the heat sensitive element is held in the open air, a change in the resistance value of the heat sensitive element which varies with the amount of water vapor contained in the open air is detected and the humidity of the open air is obtained from the amount of change in the resistance value of the heat sensitive element.

A hygrometer to carry out the method is characterized by a heat sensitive element having a temperature-resistance characteristic and held in a manner to be exposable to the open air;
a temperature compensating element having substantially the same temperature-resistance characteristic as the heat sensitive element and held in a completely dry state;
two resistors;
the heat sensitive element, the temperature compensating element and two resistors forming a bridge circuit;
a power source for supplying a current to the heat sen-

sitive element and the temperature compensating element to heat them up to a temperature above the open air temperature; and

voltage measuring means for measuring as the absolute humidity of the open air, an unbalanced output voltage from the bridge circuit which is caused by a change in the resistance value of the heat sensitive element which varies with the amount of water vapor contained in the open air.

A further embodiment is characterized by a heat sensitive element having a temperature-resistance characteristic and held in a manner to be exposable to the open air;

a temperature compensating element having substantially the same temperature-resistance characteristic as the heat sensitive element and held in a completely dry state;

two resistors;

the heat sensitive element, the temperature compensating element and two resistors forming a bridge circuit;

a power source for supplying a current to the heat sensitive element and the temperature compensating element to heat them up to a temperature above the open air temperature; and

a temperature compensating amplifier for amplifying an unbalanced output voltage from the bridge circuit, caused by a change in the resistance value of the heat sensitive element corresponding to the amount of water vapor contained in the open air, in such a manner that the amplification factor may vary with the open air temperature and the output corresponding to the relative humidity of the open air may have nothing to do with the open air temperature; and

voltage measuring means supplied with the output voltage from the temperature compensating amplifier to indicate the relative humidity.

Further, the absolute or relative humidity of the air is directly read.

Embodiments of the invention and diagrams to illustrate the operation of the embodiments are subsequently described with reference to the drawings:

Figure 1 is a diagram illustrating an embodiment of this invention.

Figure 2 is explanatory of a heat sensitive element structure of this invention.

Figure 3 is a graph showing the relationship between temperature and a bridge unbalanced output voltage in the case of a thermistor being employed, with relative humidity used as a parameter.

Figure 4 is a graph showing an example of the current-voltage characteristic of the thermistor.

Figure 5 is a circuit diagram for measuring the characteristic of the heat sensitive element for use in this invention.

Figure 6 is a graph showing an example of the current-voltage characteristic of platinum.

Figure 7 is a graph showing the relationship between temperature and a bridge unbalanced output voltage in the case of a platinum element being employed, with relative humidity used as a parameter.

Figure 8 is a circuit diagram illustrating another embodiment of this invention.

Figure 9 is a circuit diagram illustrating another embodiment of this invention.

Figure 10 is a graph showing the relationship between relative humidity and a bridge unbalanced output voltage, with temperature used as a parameter.

Figure 11 is a graph showing another example of the current-voltage characteristic of the platinum element.

Figure 12 is a graph showing the relationship between relative humidity and a bridge unbalanced output voltage in the case of the platinum element being employed, with temperature used as a parameter, and

Figures 13 and 14 are circuit diagrams respectively illustrating different examples of temperature compensating amplifiers for use in this invention.

Figure 1 is a circuit diagram illustrating an embodiment of this invention, which comprises a thermistor, platinum or like heat sensitive element R_{S1} which is held to be exposable to the open air and has a temperature-resistance characteristic, a thermistor , platinum or like temperature compensating element R_{C1} which is held in a completely dry state (in which the temperature compensating ele-

ment is hermetically sealed in an envelope together with a dry gas), a bridge circuit composed of two resistors R_2 and R_3 and a variable resistor R_4 for zero adjustment use, a power source E_1 connected with the bridge circuit via a resistor R_1 for current limiting use, a load resistor R_5 connected between terminals T_1 and T_2 and a voltmeter V_1 for measuring a bridge unbalanced output voltage which occurs across the load resistor R_5.

The heat sensitive element R_{S1} for use in the present invention has a construction such, for example, as shown in Figure 2. In Figure 2, reference numeral 1 indicates a thermistor coated with glass; 2 designates a metal case; 3 identifies a hermetic seal; 4 and 4' denote lead wires; and 5 represents holes. The metal case 2 is hermetically sealed by the hermetic seal 3 but has four to eight holes 5, for example, about o,5 mm in diameter, permitting the thermistor 1 to be exposed to the open air. On the other hand, since the temperature compensating element R_{C1} must be held in the absolutely dry state, it is sealed, together with a dry gas, in a metal case having no holes. In this case, however, the heat sensitive element R_{S1} and the temperature compensating element R_{C1} must be equipped with substantially the same current-voltage characteristic; furthermore, it is preferred that the both elements are placed adjacent to each other to hold them at the same temperature in an atmosphere with zero relative humidity.

For humidity measurement by the circuit depicted in Figure 1, the first step is to apply a voltage via the resistor R_1 to the bridge circuit from the power source E_1 so that a predetermined current flows in the heat sensitive element R_{S1} and the temperature compensating element R_{C1} to

put them in their self-heat state (about 200°C). Then, for initial adjustment, the heat sensitive element R_{S1} is held in an atmosphere with zero relative humidity and the variable resistance R_4 is adjusted so that a bridge unbalanced output voltage occuring across the lard resistor R_5, i.e. between the terminals T_1 and T_2 may be reduced to zero. After the initial adjustment, the heat sensitive element R_{S1} is contacted with the open air to start measurement. When the heat sensitive element R_{S1} is exposed to the open air, if the amount of vapor is large, that is, if the humidity of the open air is high, the amount of heat given off by the heat sensitive element R_{S1} increases to decrease its temperature, resulting in its resistance value varying. The temperature drop of the heat sensitive element R_{S1} is considered to be caused by a difference in thermal conductivity between the air and water vapor. The thermal conductivity K of gas is given by the following equation (1) :

$$K = \frac{1}{4}\left(\frac{9Cp}{Cv} - 5\right)\eta\, Cv \qquad (1)$$

where η is the coefficient of viscosity, Cv is the specific heat at constant colume and Cp is the specific heat at constant pressure.

In the present embodiment, the heat sensitive element R_{S1} is heated up to about 200°C above the open air temperature for humidity measurement. The thermal conductivities of the air and water vapor at 200°C, obtained by the equation (1), are 8.64×10^{-5} cal/cm.sec.°C and 10.1×10^{-5}cal/cm.sec.°C respectively. Thus, at 200°C, the thermal conductivity of the water vapor is higher than the thermal conductivity of the air. Accordingly, an increase in the amount of water vapor contained in the air, that is ,the

humidity of air causes an increase in the thermal conductivity of that air around the heat sensitive element R_{S1} which is the atmosphere whose humidity is to be measured, resulting in increased amount of heat given off by the heat sensitive element R_{S1} to decrease its temperature.

A change in the resistance value of the heat sensitive element R_{S1} by this temperature drop is very small, but the bridge circuit becomes unbalanced to yield a bridge unbalanced output voltage across the terminals T_1 and T_2. The unbalanced bridge output voltage corresponds to the change in the resistance value of the heat sensitive element R_{S1} and increases with an increase in humidity. Also with an increase in the open air temperature, the bridge unbalanced output voltage increases.

Figure 3 is a graph showing, with relative humidity used as a parameter, the relationships between the bridge unbalanced output voltage and the open air temperature in the case of using the thermistor of Figure 2 as each of the heat sensitive element R_{S1} and the temperature compensating element R_{C1}. As shown in Figure 3, the bridge unbalanced output voltage varies not only with the humidity change but also with the open air temperature change, but if the bridge unbalanced output voltage and the open air temperature at the time of humidity measurement are both known, accurate humidity can be obtained using such a characteristic graph as depicted in Figure 3. That is, by measuring the bridge unbalanced output voltage with the voltmeter V_1 and measuring the open air temperature at the time of humidity measurement,

accurate humidity is available. Next, a description will be given of measured results of the relationship between the unbalanced bridge output voltage and the open air temperature in the present embodiment, using humidity as a parameter.

(1) In the case where there were employed in the circuit of Figure 1, as the heat sensitive element R_{S1} and the temperature compensating element R_{C1}, thermistors having such a current-voltage characteristic (at an ambient temperature of 25°C) shown in Table 1:

Table 1

Current (mA)	Voltage (V)	Tempe rature of the thermistor (°C)
0.1	0.828	25.6
0.2	1.59	26.6
0.5	2.96	34.8
1.0	3.62	49.5
2.0	3.58	72.5
5.0	2.84	117.0
10.0	2.21	162.0
15.0	1.87	182.5
20.0	1.65	217.5

Figure 4 shows a characteristic curve obtained by plotting the results given in Table 1. The resistance values of the resistors R_1 to R_3 and R_5 used were o.389 kΩ, 10.o4 kΩ, 1o.04 kΩ and 49.47 kΩ respectively, and the voltage of the power source E_1 was 9.88 V. A current that flowed in the heat sensitive element R_{S1} and the temperature compensating element R_{C1} was 14.98 mA at an ambient temperature of 10°C, and the tempe rature of the heat sensitive element R_{S1} and the temperature compensating element R_{C1} was approximately 200°C.

It is Figure 3 that is a graphical representation of the relationships between the bridge unbalanced output voltage across the result R_5 and the open air temperature which were measured using relative humidity as a parameter, with constants of the respective parts of the measuring circuits set as described above and the heat sensitive element R_{S1} and the tempe rature compensating element R_{C1} put in their self-heat condition.

Table 2 shows some of the measured data.

Table 2

Temperature (C°)	Relative humidity (%)	Output voltage (mA)
10.0	80	1.26
	60	0.94
	40	0.63
	20	0.31
20.0	80	2.32
	60	1.74
	40	1.16
	20	0.58
30.0	80	3.90
	60	2.29
	40	1.95
	20	0.97
40.0	80	6.50
	60	4.88
	40	3.25
	20	1.63

As shown in Figure 3, the bridge unbalanced output voltage varies with the humidity and temperature variations of the open air. Accordingly, by measuring the bridge unbalanced output voltage and the open air temperature at the time of humidity measurement, humidity can be obtained using such characteristic curves as shown in Figure 3.

(2) In the case where there were employed in a circuit of Figure 5, as a heat sensitive element R_{S2} and a temperature compensating element R_{C2}, platinum having such a current-voltage characteristic (at an ambient temperature of 250°C) shown in Table 3:

Table 3

Current (mA)	Voltage (mV)	Temperature of platinum (°C)
1.0315	2.9888	25.0
10.065	29.6052	29.223
20.01	59.6052	32.595
50.0	158.52	51.344
100.83	410.4	139.73
130.00	640.0	225.98
150.48	872.6	316.64
201.6	1680.2	596.47
300.0	3748.0	1129.5

Figure 6 shows a characteristic curve obtained by plotting the results given in Table 3. The resistance values of resistors R_6 and R_7 used were 1025.62Ω and 922.2 Ω respectively, and a power source E_2 was ad - justed so that the current flowing in the heat sensi- tive element R_{S2} and the temperature compensating element R_{C2} might be 130 mA.

Figure 7 is a graphical showing of the relationship between the bridge unbalanced output voltage across terminals T_3 and T_4 and the ambient temperature which were measured using relative humidity as a parameter, with the constants of the respective parts of the measuring circuit set and the heat sensitive element R_{S2} and the temperature compensating element R_{C2} put in their self-heat condition. Table 4 shows some of the measured data.

---- Table 4

Table 4

Temperature (^{o}C)	Relative humidity (%)	Output voltage (mA)
10	80	0.752
	60	0.564
	40	0.376
	20	0.188
20	80	1.256
	60	0.942
	40	0.628
	20	0.314
30	80	1.936
	60	1.452
	40	0.968
	20	0.484
40	80	2.76
	60	2.07
	40	1.384
	20	0.69

As depicted in Fig. 7, the unbalanced bridge output voltage varies in response to the humidity and temperature variations of the open air. Accordingly, by measuring the bridge unbalanced output voltage and the open air tempe rature at the time of humidity measurement, humidity can be obtained utilizing the characteristic curves shown in Figure 7 or the like.

Platinum reduces its resistance value with temperature drop, but the thermistor in the heated state increases its resistance value with temperature rise; accordingly, the bridge unbalanced output voltage in the case of employing platinum is reverse in polarity from the bridge unbalanced output voltage in the case of using the thermistor. As shown in Figures 3 and 7, however, the unbalanced output voltage exhibits the same tendency to variations with the humidity and ambient temperature changes irrespective of whether the platinum or the thermistor is used. Consequently, it is a matter of course that the heat sensitive temperature element and the temperature compensating element may be any of those which vary their resistance value with temperature.

Figure 8 is a circuit diagram illustrating another example of the circuit for the humidity measuring method of the present invention. Reference character R_{S3} indicates a thermistor, platinum or like heat sensitive element which is held in a manner to be exposable to the open air; R_{C3} designates a thermistor, platinum or like temperature compensating element which is held in the completely dry state; R_8 identifies a resistor for current limiting use; Amp denotes a differential amplifier for amplifying a difference between a voltage occurring across the heat sensitive element R_{S3} and a voltage across the temperature compensating element; V_2 represents a voltmeter; and E_3 shows a power source. In this case, it is necessary that the heat sensitive element R_{S3} and the temperature compensating element R_{C3} have substantially the same current-voltage characteristic and are placed adjacent to each other.

The humidity measurement using the circuit of Fig. 8 starts with applying a voltage from the power source E_3 to the heat sensitive element R_{S3} and the temperature compensating element R_{C3} to put them in their self-heat state at a temperature (about 200°C above the open air temperature. After this, the heat sensitive element R_{S3} is exposed to the open air to start the humidity measurement. Since the heat sensitive element R_{S3} is held so that it may be exposed to the open air, the temperature of the heat sensitive element R_{C3} lowers with an increase in the humidity if the open air and, at the same time, the resistance value of the heat sensitive element R_{S3} also varies. On the other hand, since the temperature compensating element R_{C3} is held in the completely dry state, its resistance value does not change with the variation in the humidity of the open air. Accordingly, a difference between the voltage across the heat sensitive element R_{S3} and the voltage across the temperature compensating element R_{C3} varies with the change in the humidity of the open air. In the present embodiment, this difference is amplified by the differential amplifier Amp and then measured by the voltmeter V_2.

The output voltage from the differential amplifier Amp increases with an increase in the humidity of the open air and, at the same time, varies with the temperature change of the open air; but , by measuring the output voltage from the differential amplifier Amp and the temperature of the open air at the time of humidity measurement, accurate humidity can be obtained using a conversion table or the like.

Figure 9 is a circuit diagram illustrating another embodiment of the present invention, in which a bridge cirauit is made up of a thermistor, platinum or

like heat sensitive element R_{S4} held in a manner to be freely exposable to the open air, a thermistor, platinum or like temperature compensating element R_{C4} held in the completely dry state, resistors R_{12} and R_{13} and a variable resistor R_{14} for zero adjustment use. A power source E_4 is connected via a resistor R_{11} to the bridge circuit and a resistor R_{15} is connected across terminals T_{11} and T_{12} of the bridge circuit. A voltage occurring across the terminals T_{11} and T_{12} is amplified by an amplifier AMP and its amplified output is applied to a voltmeter V_3 . The bridge circuit is identical in construction with that employed in the foregoing embodiments.

In the case where thermistors are used as the heat sensitive element R_{S4} and the temperature compensating element R_{C4} and their voltage-current characteristics are such as shown in Table 1 and Figure 4, the measured results shown in Figure 3 and Table 2 are obtained as is the case with the foregoing embodiments. From the measured results, the bridge unbalanced output voltage and the relative humidity bear substantially linear relationships as shown in Figure 10 in which temperature is used as a parameter.

The relationships between the relative humidity and the absolute temperature are such as given in Table 5, and the rate of increase ($mV/g/m^3$) in the bridge unbalanced output voltage to the change in the absolute humidity at each temperature is such as shown in Table 6.

Table 5

Temperature (°C)	Relative humidity (%)	Absolute humidity (g/m^3)	Output Voltage (mV)
10	100	9.40	1.57
	80	7.52	1.26
	60	5.64	0.94
	40	3.76	0.63
	20	1.88	0.31
20	100	17.28	2.90
	80	13.824	2.32
	60	10.368	1.74
	40	6.912	1.16
	20	3.456	0.58
30	100	30.34	4.87
	80	24.272	3.90
	60	18.204	2.92
	40	12.136	1.95
	20	6.068	0.97
40	100	51.1	8.13
	80	40.88	6.50
	60	30.66	4.88
	40	20.44	3.25
	20	10.22	1.63

Table 6

Temperature (°C)	Rate of increase ($mV/g/m^3$)
10	0.167
20	0.1678
30	0.1605
40	0.1591

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As seen from Table 6, the bridge unbalanced output voltage presents substantially the same rate of increase with respect to the increase in the absolute humidity at each temperature. Accordingly, by amplifying the bridge unbalanced output voltage across the terminals T_{11} and T_{12} of the bridge circuit by the amplifier AMP serving as a linear amplifier and applying the amplified output to the voltmeter V_3 graduated in terms of absolute humidity, the absolute humidity can be direct-read from the indication of the voltmeter V_3. In other words, an absolute hygrometer can be obtained which electrically measures absolute humidity.

In the case of using platinum elements as the heat sensitive element R_{S4} and the temperature compensating element R_{C4}, when the current-voltage characteristics of the platinum are such as shown in Table 3 and Figure 6, the measured results shown in Figure 7 and Table 4 are obtained as is the case with the foregoing embodiment employing the platinum elements.

It is also possible to use platinum elements having such a current-voltage characteristic as shown in Table 7, and Figure 11 shows a curve by plotting the values given in Table 7.

Table 7

Current (mA)	Voltage (mV)	Temperature of platinum (°C)
1.0092	2.8348	25.0
10.019	28.3157	26.706
20.00	57.08	29.466
49.97	150.989	46.153
101.3	380.7	120.50
130.0	600.0	209.41
150.7	779.9	268.55
200.5	1462.3	504.01
300.1	3469.97	1049.8

From the measured results shown in Table 4, the relationships between the absolute humidity and the relative humidity shown in Table 8 are obtained. The relative humidity and the bridge unbalanced output voltage bear such relationships as shown in Figure 12 in which temperature is used as a parameter.

Table 8

Temperature (°C)	Relative humidity (%)	Absolute humidity (g/m^3)	Output voltage (mV)
10	100	9.40	0.940
	80	7.52	0.752
	60	5.64	0.564
	40	3.76	0.376
	20	1.88	0.188
20	100	17.28	1.570
	80	13.324	1.256
	60	10.368	0.942
	40	6.912	0.628
	20	3.456	0.314
30	100	30.34	2.420
	80	24.272	1.936
	60	18.204	1.452
	40	12.136	0.968
	20	6.068	0.484
40	100	51.10	3.45
	80	40.88	2.76
	60	30.60	2.07
	40	20.44	1.38
	20	10.22	0.69

Table 9 shows how much the bridge unbalanced output voltage increases each time the absolute humidity increases by $1g/m^3$ at each temperature.

Table 9

Temperature (°C)	Rate of increase (mV/g/m³)
10	0.1
20	0.0908
30	0.0798
40	0.068

In the case of employing platinum elements as the heat sensitive element R_{S4} and the temperature compensating elements R_{C4}, the rate of increase in the bridge unbalanced output voltage differs for each temperature, as shown in Table 9. However, since the bridge unbalanced output voltage varies in proportion to the change in the absolute humidity at one point of temperature, if the platinum elements are used in an atmosphere of constant ambient temperature, direct reading of the absolute humidity is possible by measuring the bridge unbalanced output voltage. For direct reading of the absolute humidity regardless of the ambient temperature, a temperature compensating amplifier whose amplification factor varies with temperature is connected across the terminals T_{11} and T_{12} and the rate of increase in the output voltage from the temperature compensating amplifier is held constant regardless of the ambient temperature. That is, the temperature compensating amplifier is used as the amplifier AMP.

Figure 13 is a circuit diagram illustrating an example of the temperature compensating amplifier. In Figure 13, reference characters T_{11}' and T_{12}' indicate terminals for connection with the terminals T_{11} and T_{12} of the bridge circuit; OP designates an operational

amplifier; Th identifies a thermistor; R_{21} to R_{27} denote resistors; C represents a capacitor; and OUT shows an output terminal. In this case, since the thermistor Th is connected to a feedback circuit of the operational amplifier OP, the amplification factor of the operational amplifier OP varies with the ambient temperature. As a consequence, the rate of increase in the output voltage available from the output terminal OUT can be made constant regardless of the ambient temperature. Accordingly, by connecting a voltmeter to the output terminal OUT, direct reading of absolute humidity is possible.

It is a matter of course that the temperature compensating amplifier may be any type of amplifier so long as the abovesaid object can be achieved. Also in the case of using thermistors as the heat sensitive element and the temperature compensating element, the accuracy of measurement can be enhanced by employing such a temperature compensating amplifier.

Since relative humidity varies with the open air temperature as described previously, a relative hygrometer can be constituted by such an arrangement that changes the amplification factor of the amplifier AMP in Figure 9 with temperature and permits direct reading of the relative humidity by the voltmeter V_3 graduated in terms of relative humidity.

Figure 14 is a circuit diagram illustrating an example of a temperature compensating amplifier whose amplification factor is changed with temperature for direct reading of the relative humidity. In Figure 14, reference characters T_{11}" and T_{12}" indicate terminals for connection with the terminals T_{11} and T_{12} of the bridge circuit in Figure 9; R_{31} to R_{43} designate resistors;

C_1 identifies a capacitor; OP_1 and OP_2 denote operational amplifiers; Th_1 and Th_2 represent thermistors; and OUT' shows an output terminal for connection with the voltmeter V_3.

The operational amplifier OP_1 amplifies the bridge unbalanced output voltage and provides the amplified output to the operational amplifier OP_2 of the next stage. Since the thermistor Th_1 is connected to a feedback circuit of the operational amplifier OP_1, the resistance value of the thermistor varies with the open air temperature to cause a change in the amplification factor of the operational amplifier OP_1. The operational amplifier OP_2 is identical in construction with the operational amplifier OP_1, and accordingly the amplification factor of the operational amplifier OP_2 varies with the open air temperature.

When temperature falls, the resistance values of the thermistors Th_1 and Th_2 increase to cause a decrease in the feedback from the output side to the input side of the operational amplifiers OP_1 and OP_2, resulting in their amplification factor becoming large. Accordingly, by determining the change in the amplification factor withtemperature in a manner to compensate for the variations in temperature and relative humidity shown in Figure 3, relative humidity can be read directly from the voltmeter V3 connected to the output terminal OUT'. The bridge unbalanced output voltage, for example, at 30°C, is 2.5 mV to indicate a relative humidity of 50%; in the case where the amplification factor at this time is regarded as 100 and a voltage of 250 mV is yielded, if the temperature drops to 20°C, the bridge unbalanced output voltage becomes 1.4 mV. Then, by changing the amplification factor to 178 corresponding to the temperature change as described

above, the voltage of 250 mV is provided again, and accordingly, the indication of the voltmeter V_3 shows the relative humidity 50% without undergoing any change. Therefore, even if the open air temperature changes without any change in the relative humidity, the output voltage at the output terminal OUT' does not vary; hence, the relative humidity can be indicated on the voltmeter V_3 so that it can be read directly therefrom. Since the temperature compensating amplifier of Figure 14 is easy of increasing its amplification factor with temperature change, as compared with the temperature compensating amplifier of Figure 13, the former is suitable for use in measuring the relative humidity regardless of temperature.

As has been described in the foregoing, according to the present invention, a current is applied to a thermistor, platinum or like heat sensitive element to heat it up to a temperature above the open air temperature; the heat sensitive element is held in the open air to cause its resistance value to vary with the quantity of water vapor contained in the open air; and the resistance value is measured, thereby to obtain relative or absolute humidity. The absolute humidity indicates the quantity of water vapor (g/m^3) contained in the open air and when the open air temperature drops to the temperature at which this quantity of water vapor corresponds to the quantity of satured water vapor, the temperature at that time represents the dew-point temperature. Accordingly, the dew-point temperature can be obtained from the absolute humidity. In other words, by graduating the absolute hygrometer in terms of dew-point temperature, the dew-point can be read directly from the absolute hygrometer.

The voltmeter may also be a digital voltmeter; in this case, by providing the amplifier for amplifying the bridge unbalanced output voltage with the temperature compensating characteristic corresponding to the purpose of measuring the absolute or relative humidity and the characteristic of the heat sensitive element used, the absolute or relative humidity can be read directly from the digital voltmeter without regard to variations in the open air temperature. This leads to the advantage of easy and highly accurate humidity measurement.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this invention.

Claims:

1. A humidity measuring method which is characterized in that a current is applied to a heat sensitive element (R_{S1}; R_{S3}; R_{S4}) having a temperature-resistance characteristic to heat it up to a temperature above the open air temperature; the heat sensitive element (R_{S1}; R_{S3}; R_{S4}) is held in the open air; a change in the resistance value of the heat sensitive element which varies with the amount of water vapor contained in the open air is detected; and the humidity of the open air is obtained from the amount of change in the resistance value of the heat sensitive element.

2. A humidity measuring method according to claim 1 which is characterized in that a heat sensitive element (R_{S1}; R_{S3}; R_{S4}) and a temperature compensating element (R_{C1}; R_{C3}; R_{C4}) having substantially the same temperature-resistance characteristic are connected in series with each other and connected to a power source (E_1; E_3; E_4); a current is applied to the heat sensitive element and the temperature compensating element to heat them up to a temperature above the open air temperature.

3. A humidity measuring method according to claim 2, characterized in that the heat sensitive element (R_{S1}; R_{S3}; R_{S4}) and the temperature compensating element (R_{C1}; R_{C3}; R_{C4}) are connected in series with each other to form one side of a bridge circuit; a power source (E_1, E_3, E_4) is connected to the bridge circuit having the other side formed by a series connection of two resistors (R_2, R_3; R_{12}, R_{13}) and a change in the resistance value of the heat sensitive element which varies with the amount of water vapor contained in the open air is detected in the form of an unbalanced output voltage from the bridge circuit.

4. A hygrometer comprising:
a heat sensitive element (R_{S1}) having a temperature-resistance characteristic and held in a manner to be exposable to the open air;

a temperature compensating element (R_{C1}) having substantially the same temperature-resistance characteristic as the heat sensitive element and held in a completely dry state;

two resistors (R_2, R_3);

the heat sensitive element, the temperature compensating element and two resistors forming a bridge circuit;

a power source (E_1) for supplying a current to the heat sensitive element (R_{S1}) and the temperature compensating element (R_{C1}) to heat them up to a temperature above the open air temperature; and

voltage measuring means (V_1) for measuring as the absolute humidity of the open air, an unbalanced output voltage from the bridge circuit which is caused by a

change in the resistance value of the heat sensitive element (R_{S1}) which varies with the amount of water vapor contained in the open air.

5. A hygrometer according to claim 4, wherein
the heat sensitive element (R_{S1}) and the temperature compensating element (R_{C1}) are formed by thermistors.

6. A hygrometer according to claim 4, wherein
the heat sensitive element (R_{S3}) and the tempe rature compensating element (R_{C3}) are formed by platinum elements, and wherein the unbalanced output voltage from the bridge circuit is amplified by a tempe rature compensating amplifier (Amp) and then applied to the voltage measuring means (V_2).

7. A hygrometer comprising:

a heat sensitive element (R_{S4}) having a temperature-resistance characteristic and held in a manner to be exposable to the open air;

a tempe rature compensating element (R_{C4}) having substantially the same temperature-resistance characteristic as the heat sensitive element (R_{S4}) and held in a completely dry state;

two resistors (R_{12}, R_{13});

the heat sensitive element, the temperature compensating element and two resistors forming a bridge circuit;

a power source (E_4) for supplying a current to the heat sensitive element and the temperature compensating

element to heat them up to a temperature above the open air temperature; and

a temperature compensating amplifier (AMP) for amplifying an unbalanced output voltage from the bridge circuit, caused by a change in the resistance value of the heat sensitive element (R_{S4}) corresponding to the amount of water vapor contained in the open air, in such a manner that the amplification factor may vary with the open air temperature and the output corresponding to the relative humidity of the open air may have nothing to do with the open air temperature; and

voltage measuring means (V_3) supplied with the output voltage from the tempe rature compensating amplifier (AMP) to indicate the relative humidity.

8. A hygrometer according to claim 7, wherein the heat sensitive element (R_{S4}) and the temperature compensating elements (R_{C4})are formed by thermistors (1).

9. A hygrometer according to claim 7, wherein the heat sensitive element (R_{S4}) and the temperature compensating element (R_{C4}) are formed by platinum elements.

1o. A hygrometer according to claim 7, wherein the temperature compensating amplifier is formed by connecting to a feedback circuit (R_{23}) of an operational amplifier (OP) a thermistor (Th) whose resistance value varies with the open air temperature.

FIG. 1

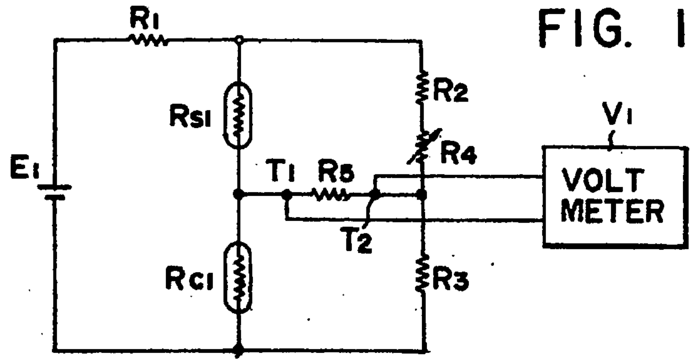


FIG. 2

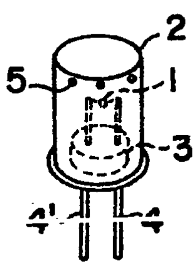


FIG. 5

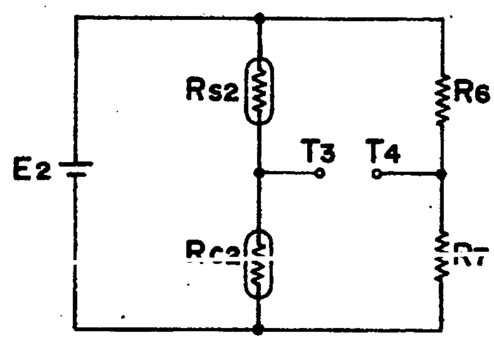


FIG. 8

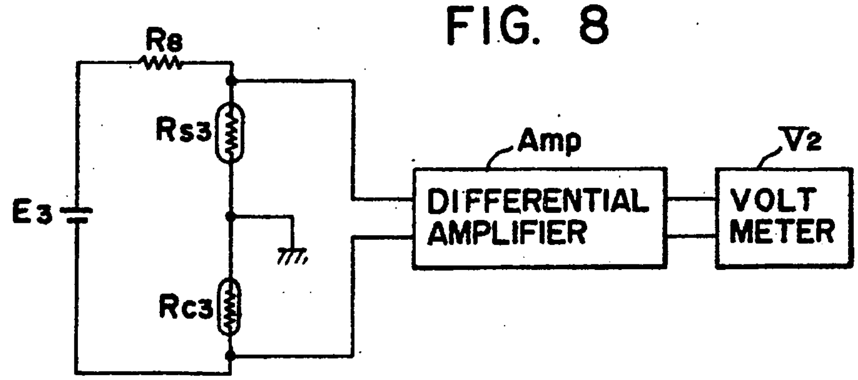
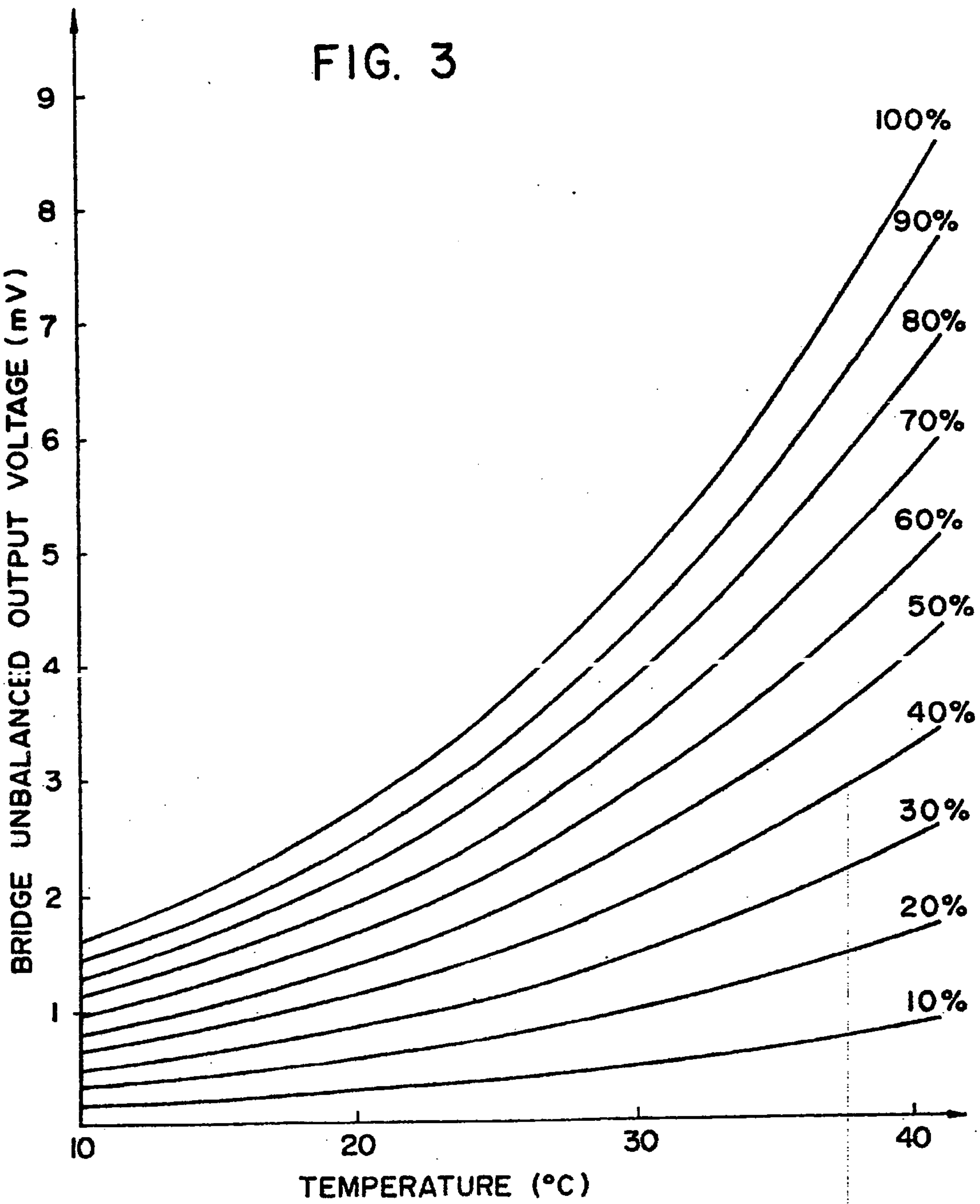


FIG. 3



BRIDGE UNBALANCED OUTPUT VOLTAGE (mV)
9
8
7
6
5
4
3
2
1
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
10
20
30
40
TEMPERATURE (°C)

FIG. 4

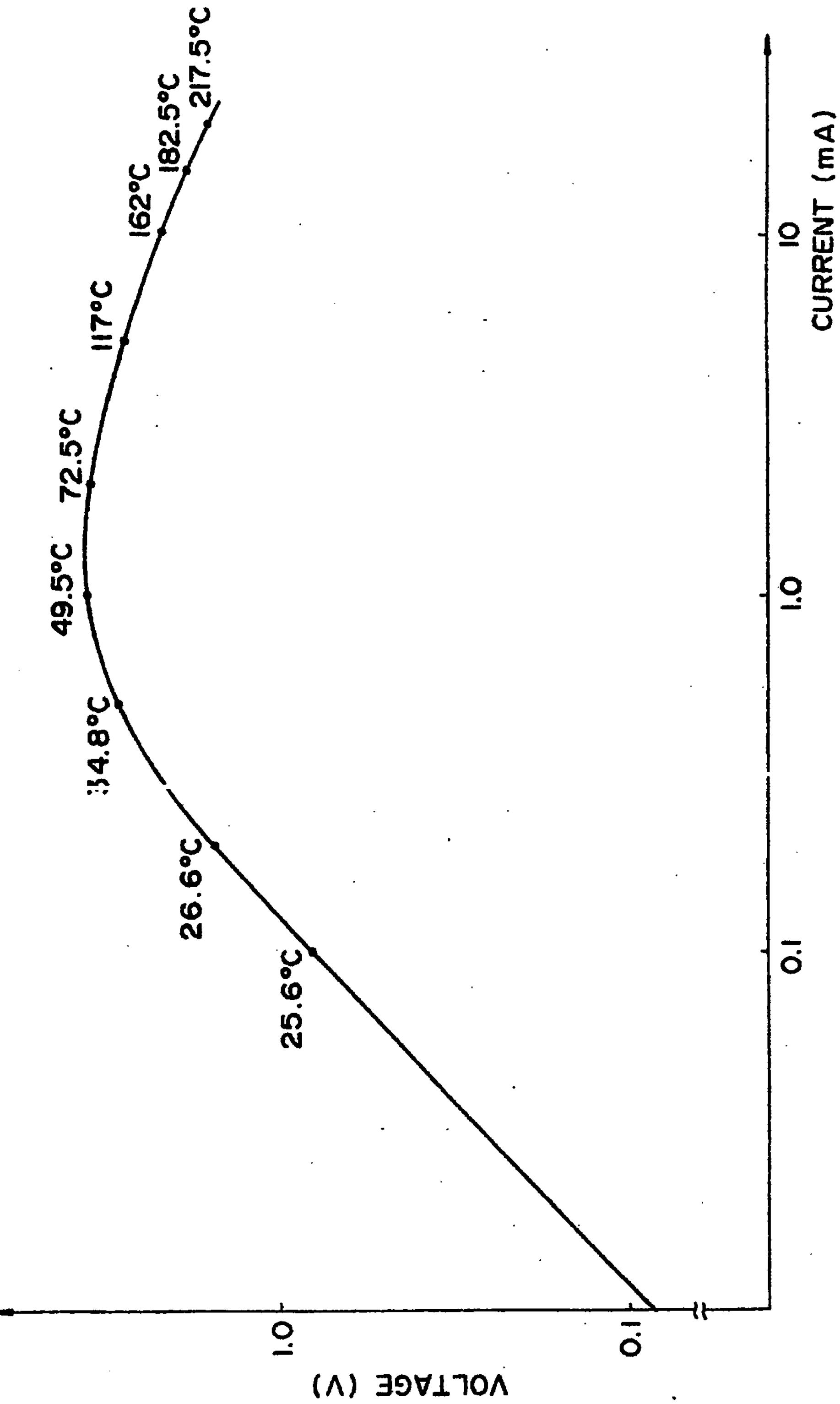

217.5°C
182.5°C
162°C
117°C
72.5°C
49.5°C
34.8°C
26.6°C
25.6°C
VOLTAGE (V)
1.0
0.1
CURRENT (mA)
0.1
1.0
10

FIG. 6

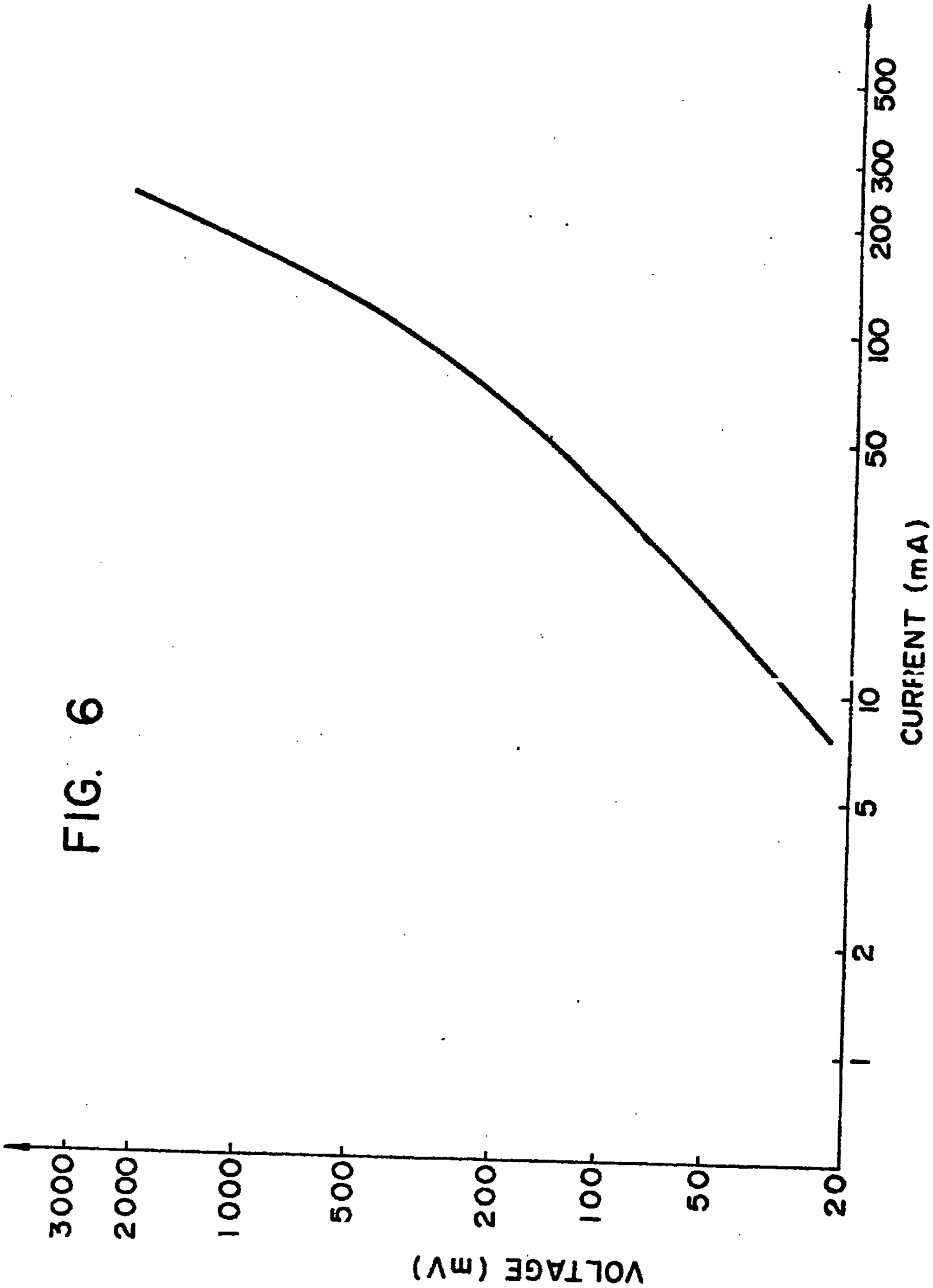
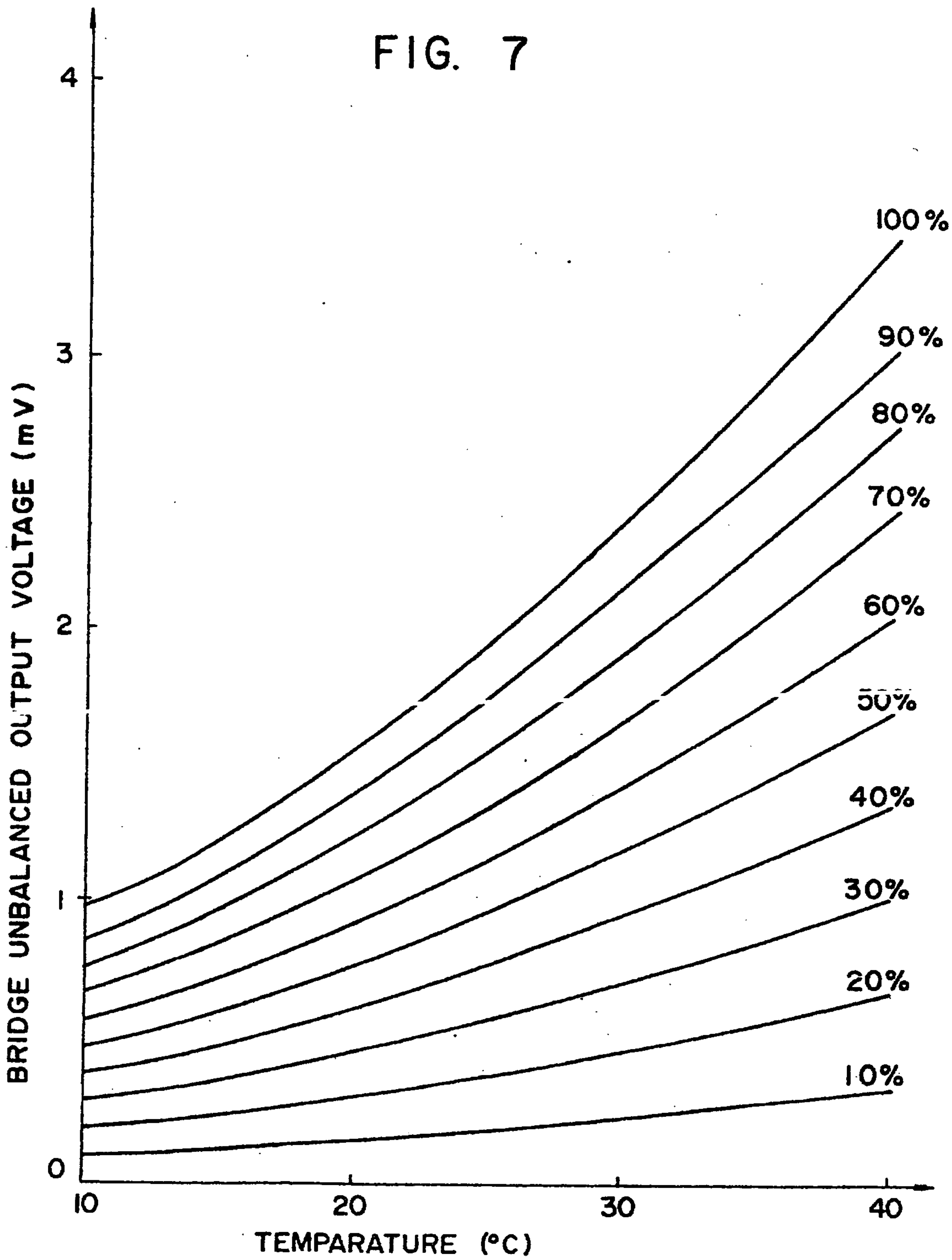

VOLTAGE (mV)
3000
2000
1000
500
200
100
50
20
CURRENT (mA)
1
2
5
10
50
100
200
300
500

FIG. 7



BRIDGE UNBALANCED OUTPUT VOLTAGE (mV)
4
3
2
1
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
10
20
30
40
TEMPARATURE (°C)

FIG. 9

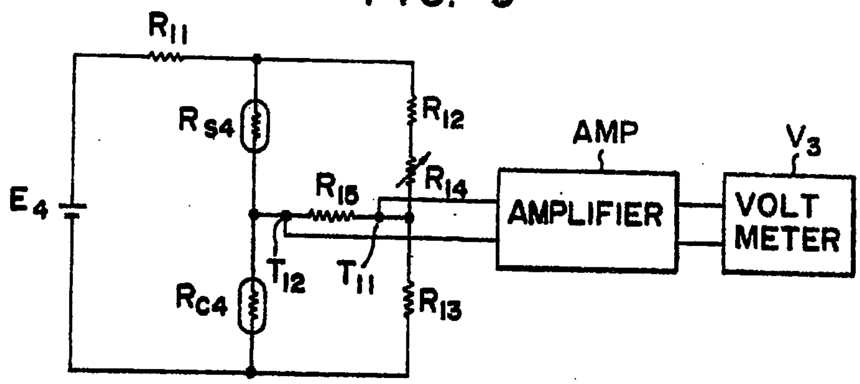

R11
RS4
R12
AMP
V3
R15
R14
E4
AMPLIFIER
VOLT METER
T12
T11
RC4
R13

FIG. 14

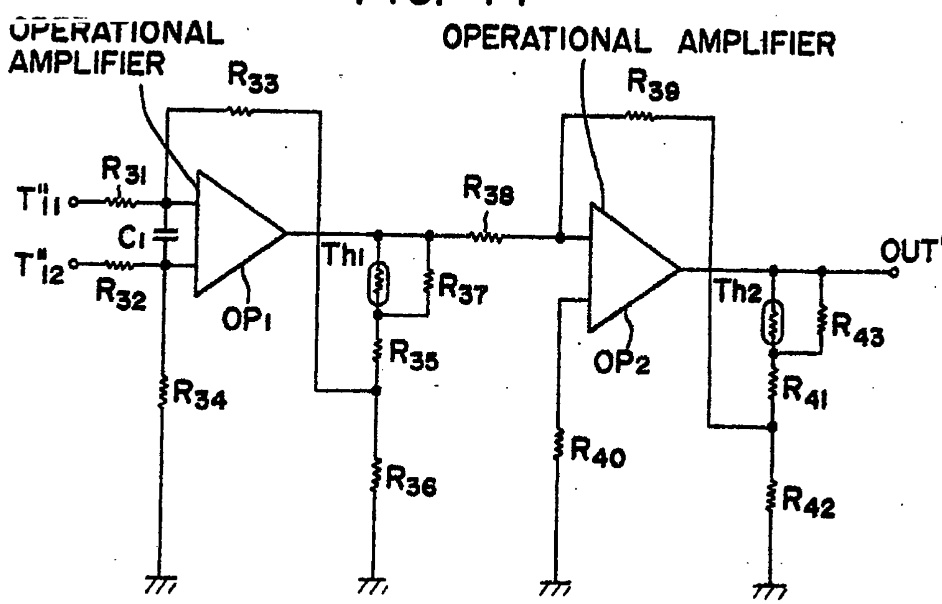
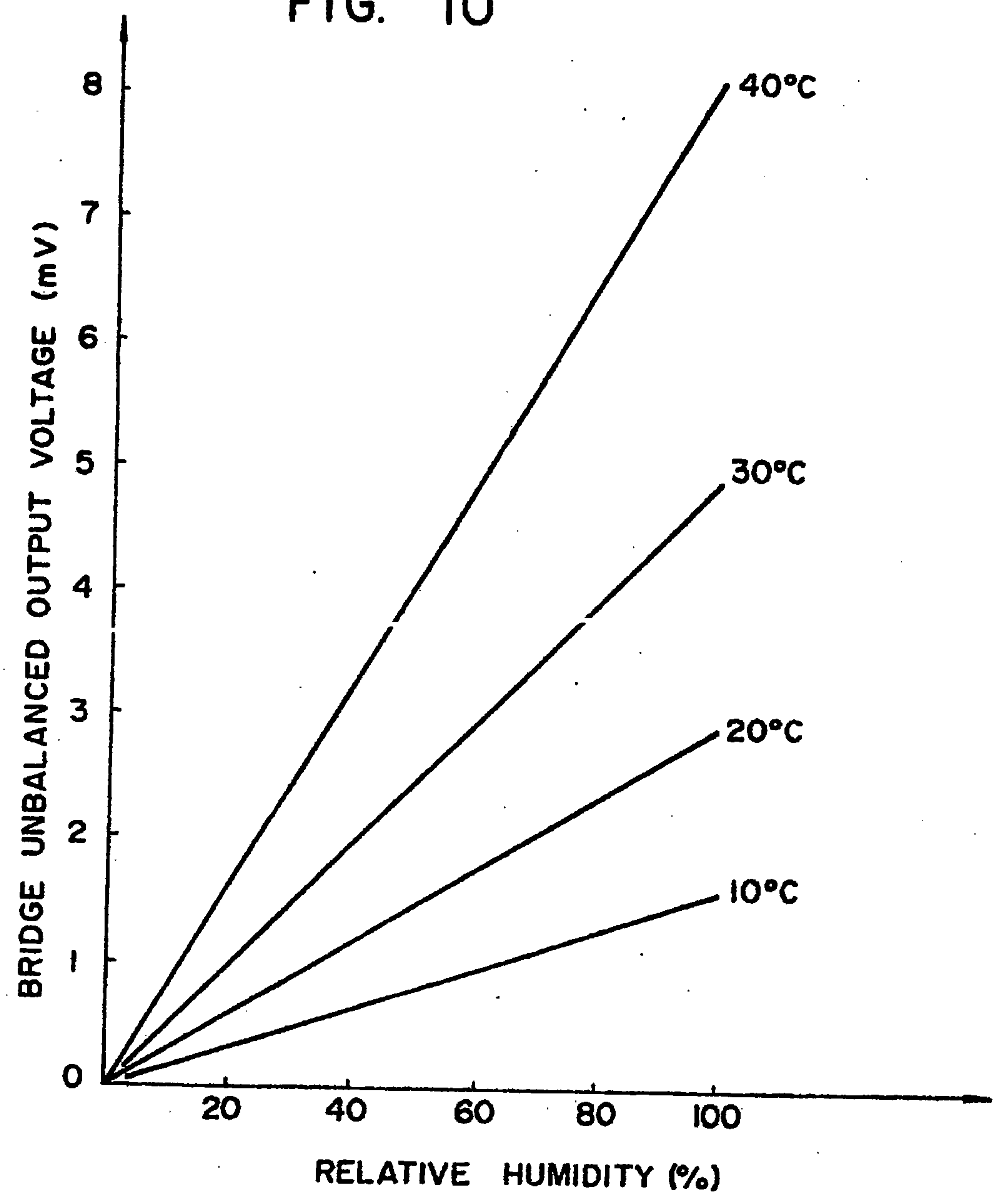

OPERATIONAL AMPLIFIER
OPERATIONAL AMPLIFIER
R33
R39
R31
T"11
R38
C1
OUT'
T"12
Th1
R37
R32
Th2
OP1
R43
R35
OP2
R41
R34
R40
R36
R42

FIG. 10


BRIDGE UNBALANCED OUTPUT VOLTAGE (mV)
0
1
2
3
4
5
6
7
8
40°C
30°C
20°C
10°C
20
40
60
80
100
RELATIVE HUMIDITY (%)

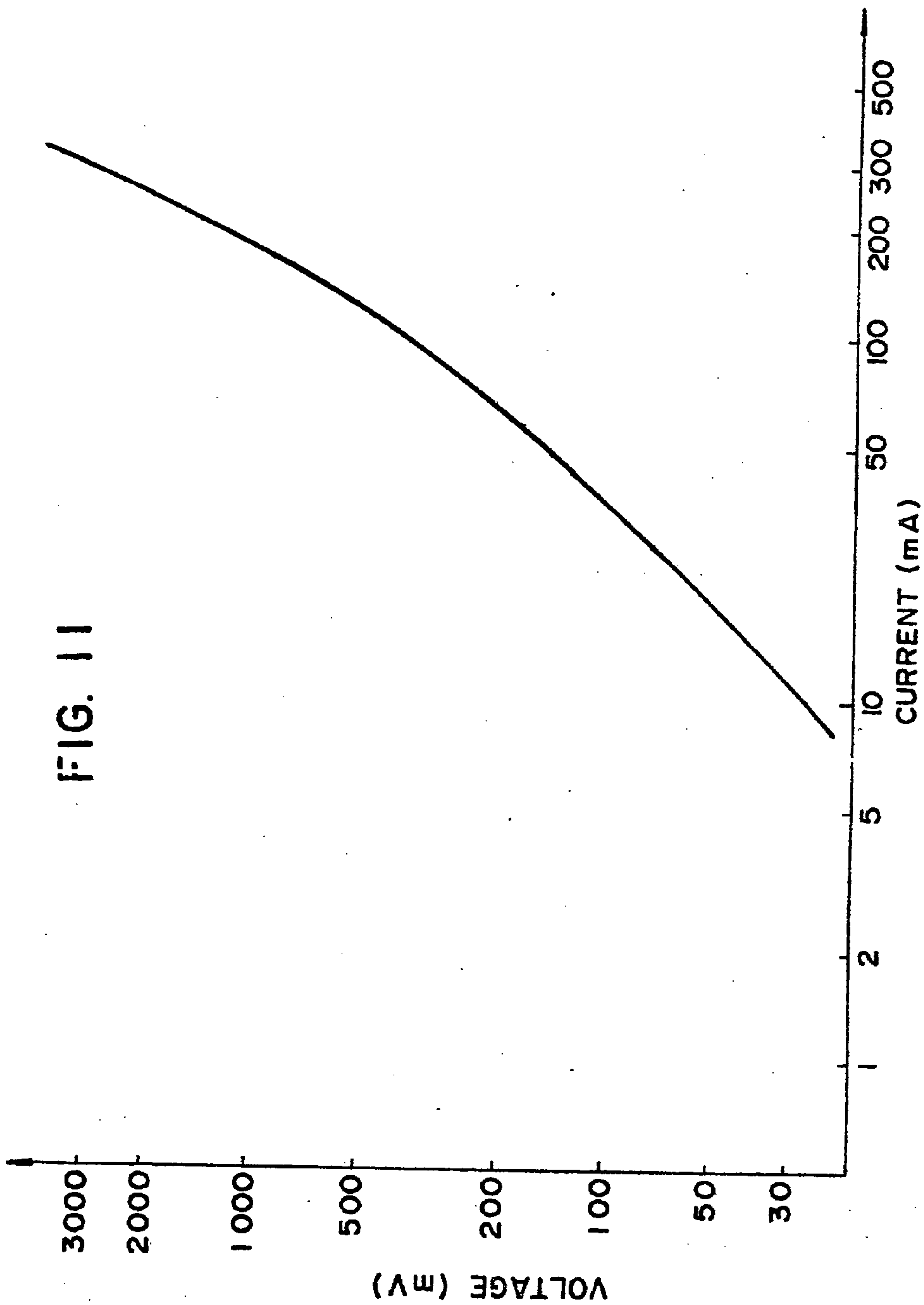
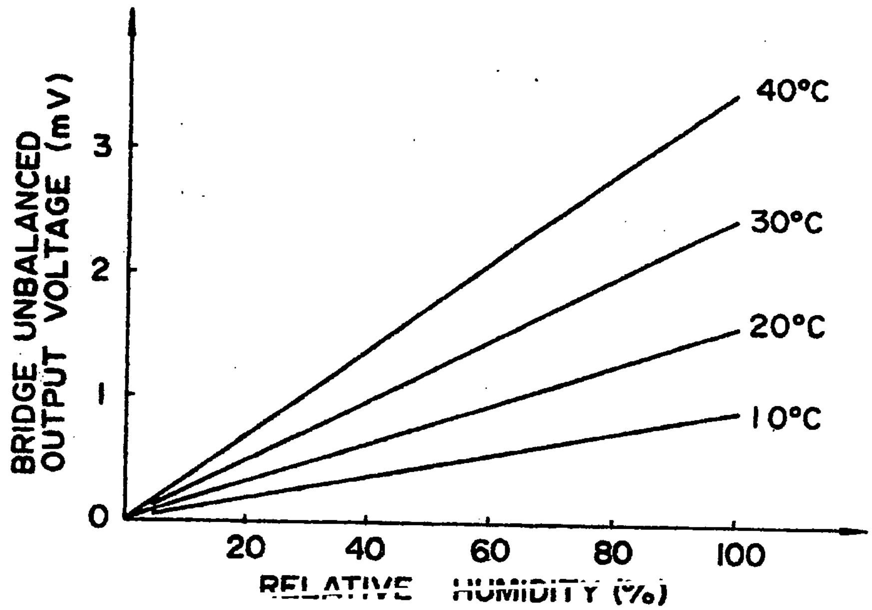

VOLTAGE (mV)
3000
2000
1000
500
200
100
50
30
CURRENT (mA)
1
2
5
10
50
100
200
300
500

FIG. 11

FIG. 12


BRIDGE UNBALANCED OUTPUT VOLTAGE (mV)
0
1
2
3
20
40
60
80
100
RELATIVE HUMIDITY (%)
40°C
30°C
20°C
10°C

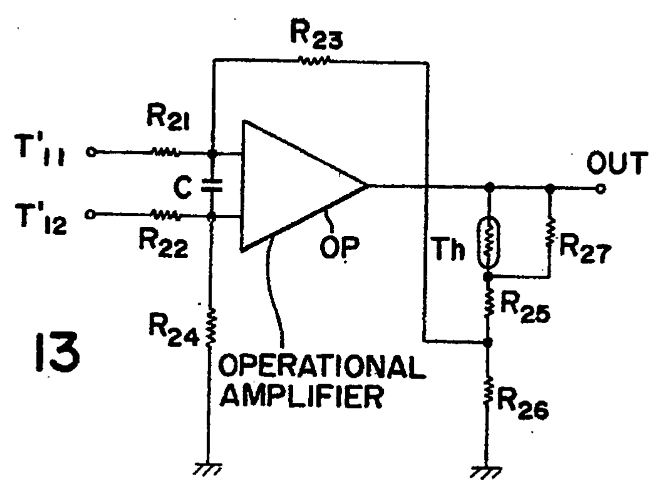

R23
R21
T'11
C
T'12
R22
OP
OUT
Th
R27
R25
R24
OPERATIONAL AMPLIFIER
R26

FIG. 13

European Patent Office

EUROPEAN SEARCH REPORT

0021225

Application number

EP 80 10 3210.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X	US - A - 1 855 774 (E. SCHNEIDER) * claims 1, 3, 4, 6, 7; fig. 1 *	1,2, 3,4
	US - A - 2 848 306 (D.R. BLUMER) * column 2, lines 63 to 67 *	5,6
A	DE - A1 - 2 756 859 (B.M. POTTER) * whole document *	
A	US - A - 2 727 968 (E.S. RITTNER et al.) * whole document *	

CLASSIFICATION OF THE APPLICATION (Int. Cl.3)

G 01 N 27/18
G 01 N 25/64

TECHNICAL FIELDS SEARCHED (Int.Cl.3)

G 01 N 25/56
G 01 N 27/04

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	26-08-1980	SCHWARTZ

EPO Form 1503.1 06.78